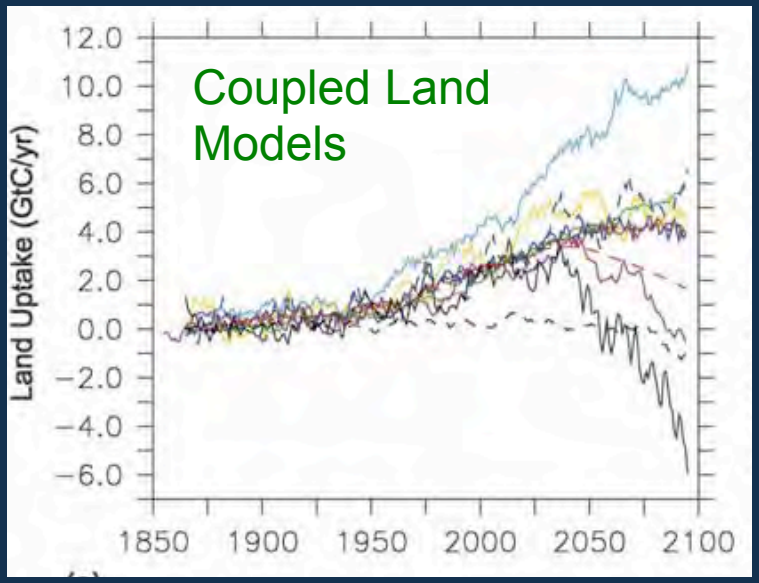
# Using observational data to evaluate global terrestrial biospheric models: challenges and opportunities?

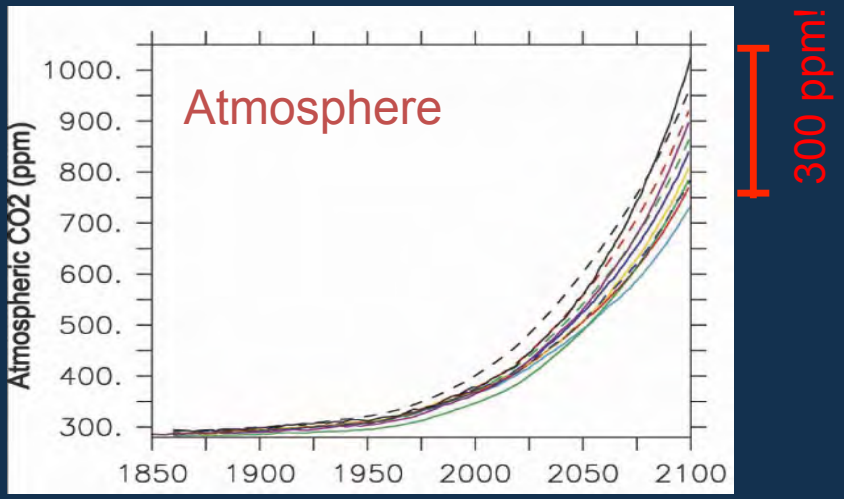
May 5th, 2014
AmeriFlux Meeting

Deborah Huntzinger
Christopher Schwalm, Anna Michalak, Joshua Fisher, Ben Poulter, Yaxing Wei, Robert Cook, Kevin Schaefer, Andrew Jacobson & MsTMIP Modeling Teams

# Future climate projections depend, in part, on ability to model land-atmosphere carbon exchange

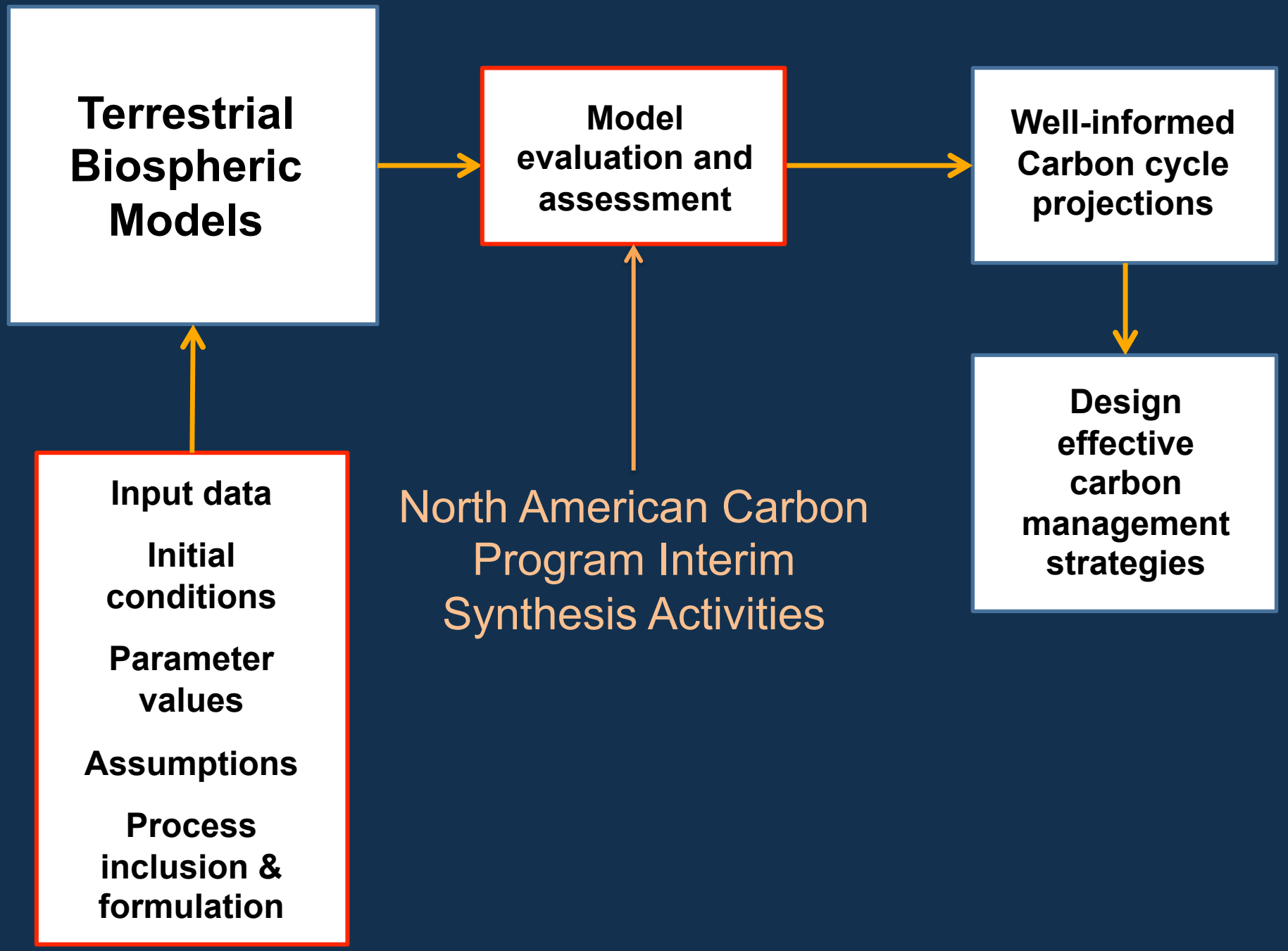



Coupled carbon-climate models disagree on the continued strength of the net land sink




Uncertainty in models translates into uncertainties in projections of future atmospheric $CO_2$

From Friedlingstein et al. 2006


Terrestrial Biospheric Models
Model evaluation and assessment
Well-informed Carbon cycle projections
Design effective carbon management strategies
Input data
Initial conditions
Parameter values
Assumptions
Process inclusion & formulation
North American Carbon Program Interim Synthesis Activities

Ecological Modelling 232 (2012) 144–157

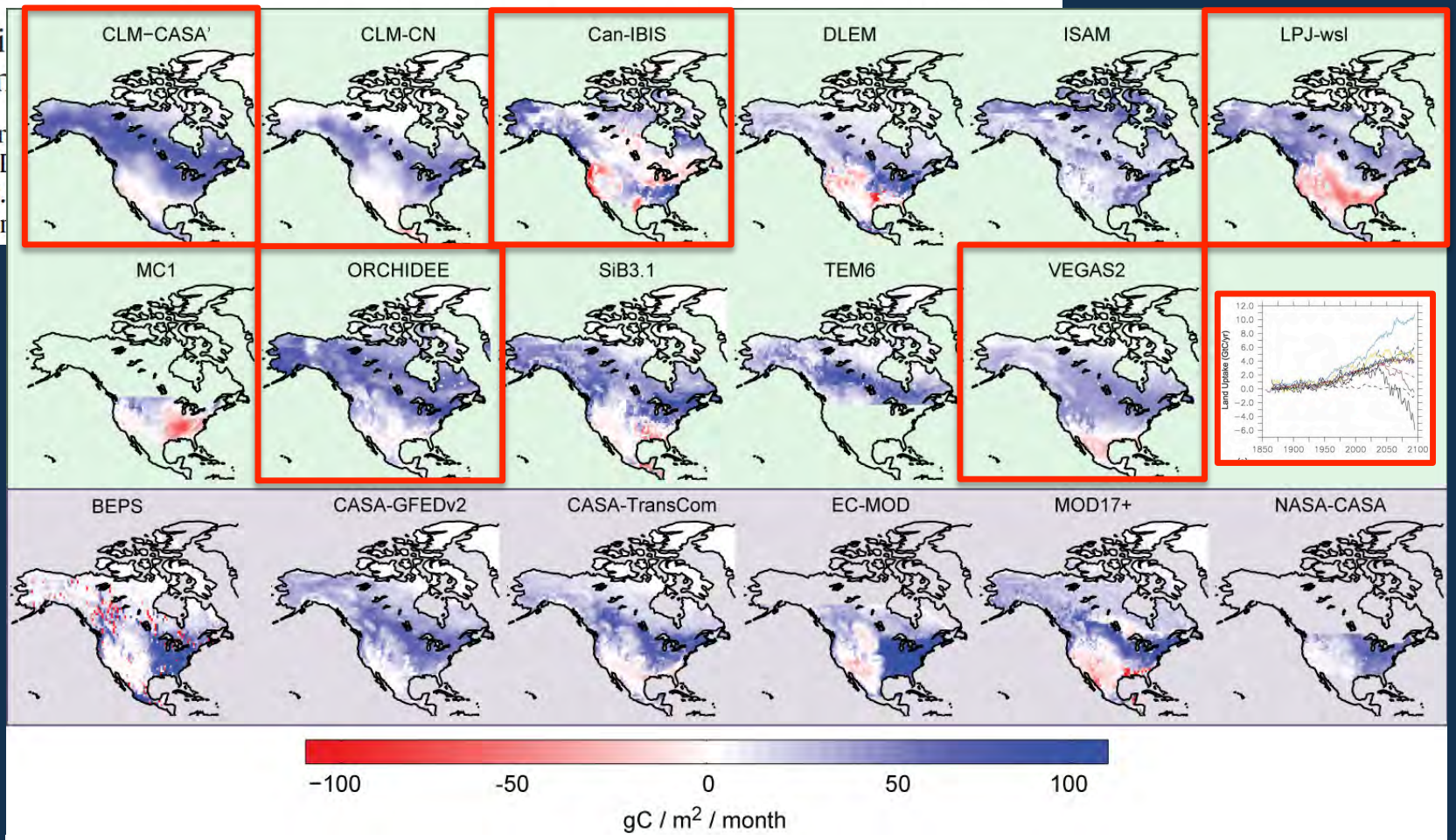
Contents lists available at SciVerse ScienceDirect

Ecological Modelling

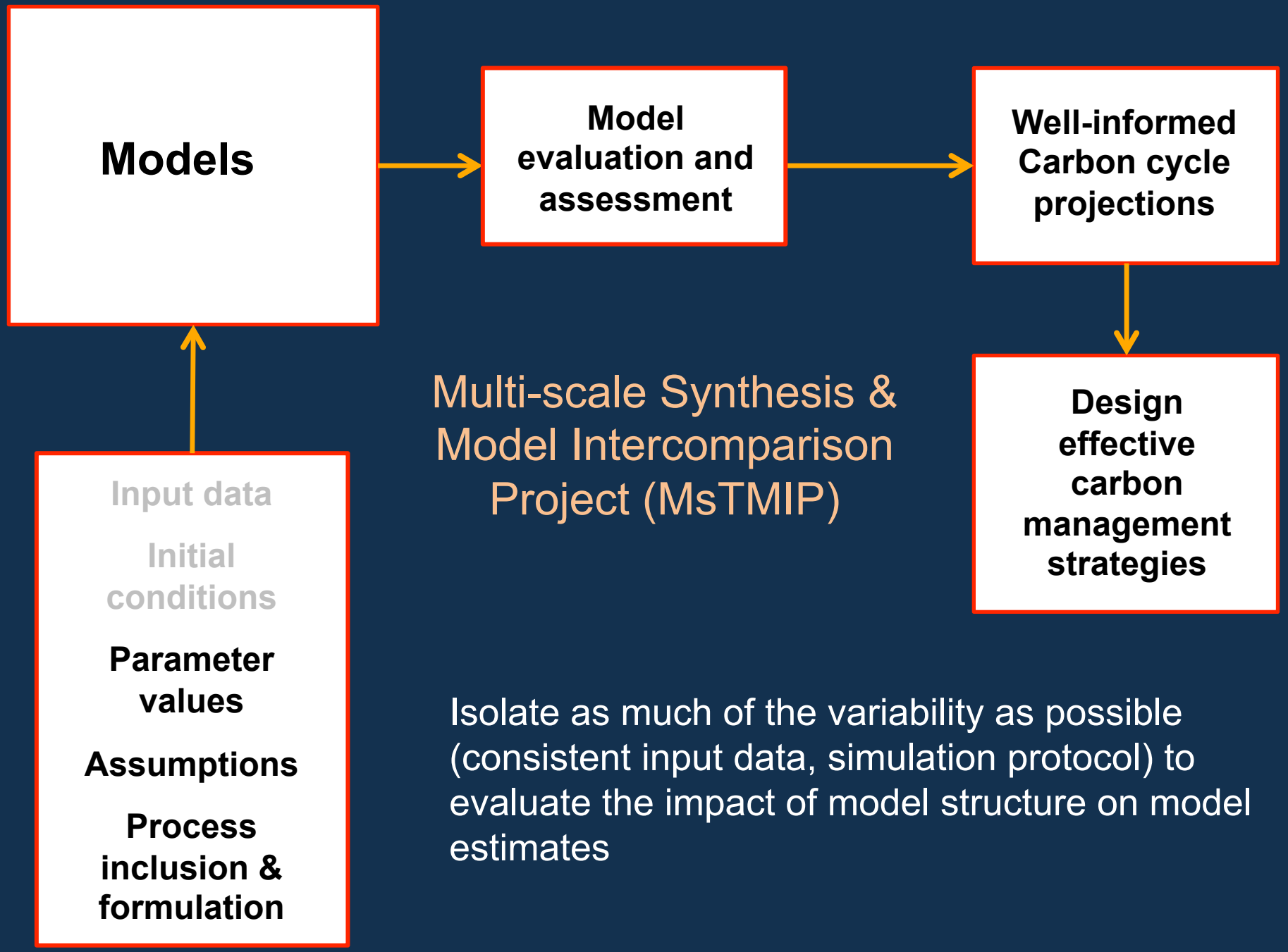
journal homepage: www.elsevier.com/locate/ecolmodel

North Ameri
biospheric m

D.N. Huntzinger
J.M. Chen[h], K.J. I
Chris Potter[n], B.
J. Xiao[s], W. Yuar




Long-Term Mean (2000-2005) Summer (June, July, August)
Net Ecosystem Productivity

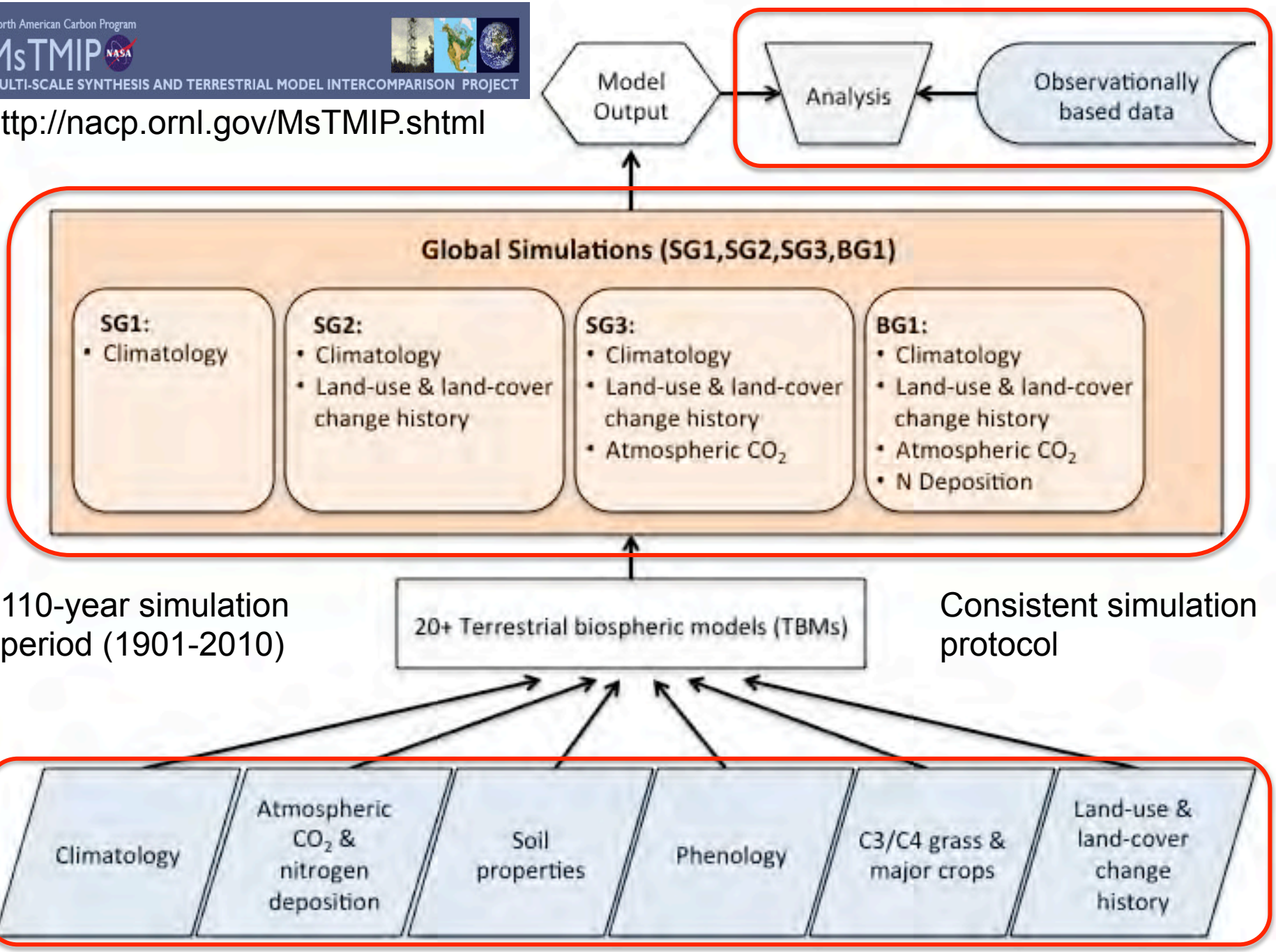

Models
Model evaluation and assessment
Well-informed Carbon cycle projections
Design effective carbon management strategies
Input data
Initial conditions
Parameter values
Assumptions
Process inclusion & formulation
Multi-scale Synthesis & Model Intercomparison Project (MsTMIP)
Isolate as much of the variability as possible (consistent input data, simulation protocol) to evaluate the impact of model structure on model estimates

North American Carbon Program

MsTMIP

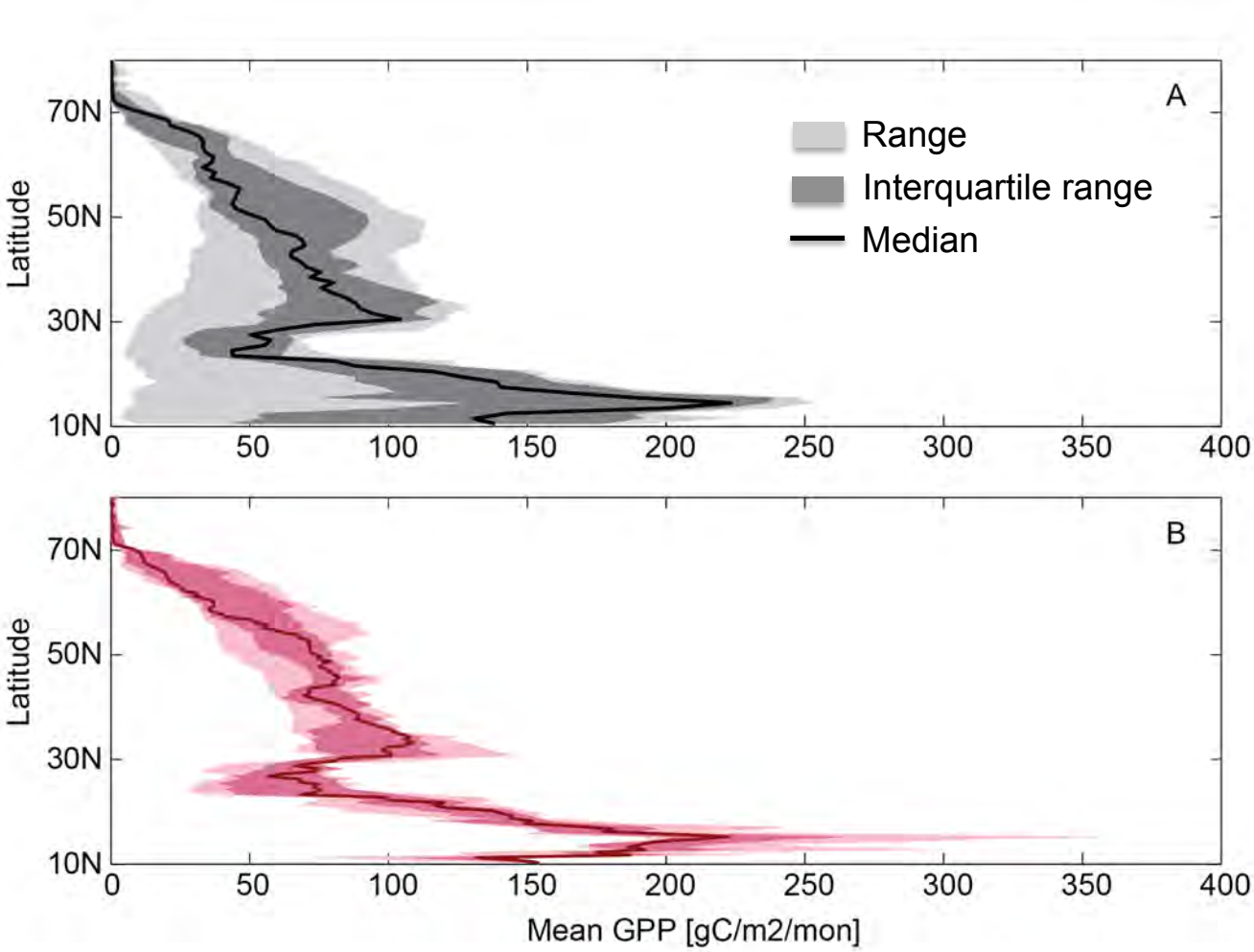
MULTI-SCALE SYNTHESIS AND TERRESTRIAL MODEL INTERCOMPARISON PROJECT

http://nacp.ornl.gov/MsTMIP.shtml




Modified from Huntzinger et al., Geoscientific Model Dev.(2013)

# Importance of MsTMIP Experimental Design:
## Mean GPP for North America (2000-2005)




NACP regional interim synthesis
"Unconstrained" protocol

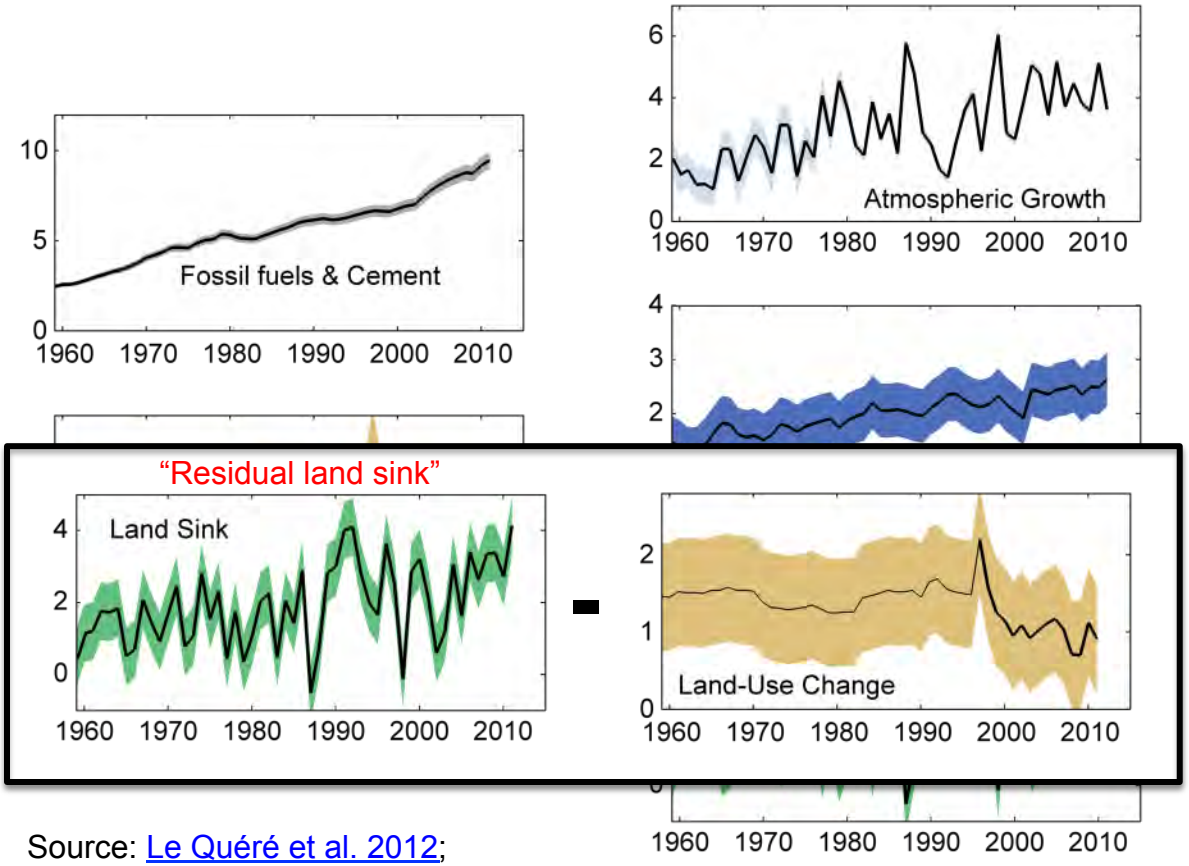
MsTMIP
"Constrained" protocol

5 models (CLM, DLEM, LPJ, ORCHIDEE, VEGAS)

Huntzinger et al., Geoscientific Model Dev. (2013)

# Compare model estimates of net land sink from to independent estimate:

## Global Carbon Project (GCP)

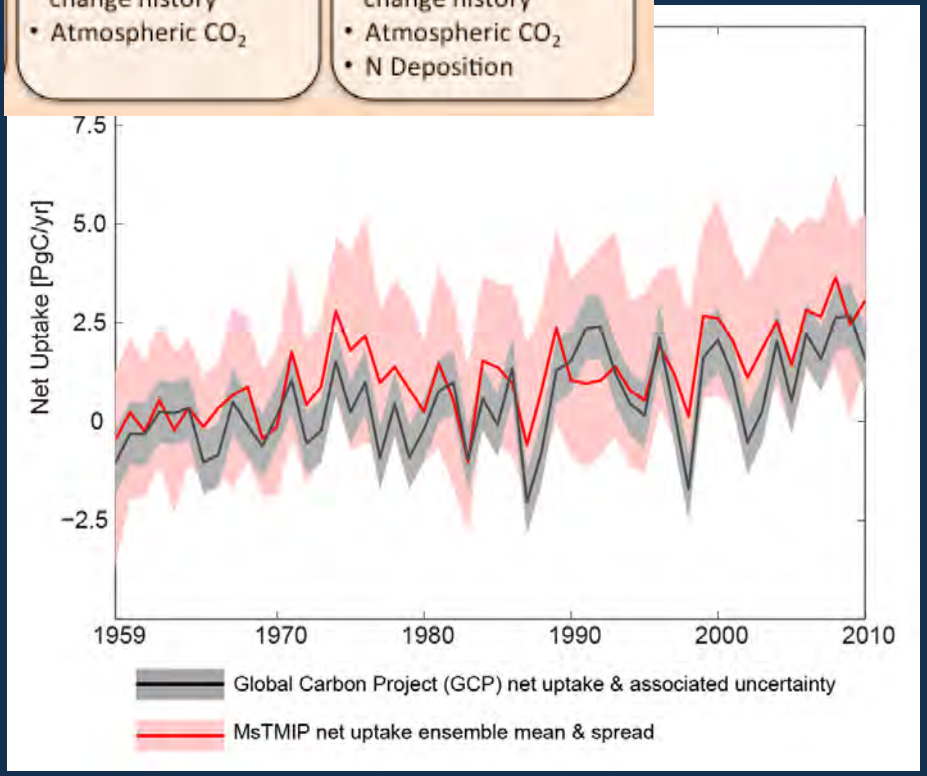


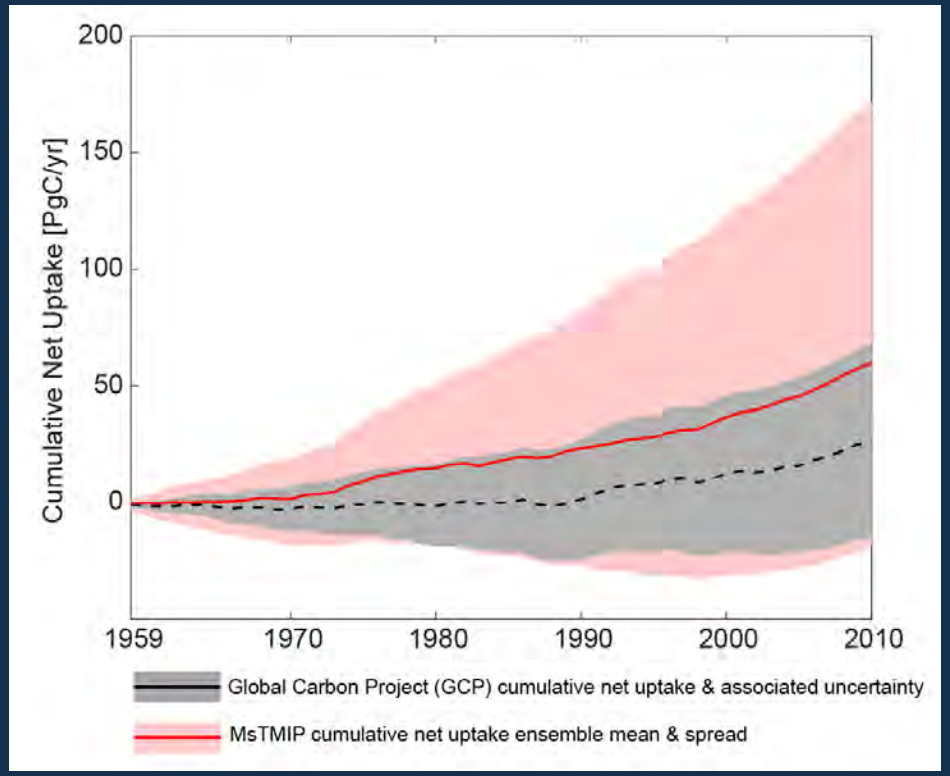

Source: Le Quéré et al. 2012; Global Carbon Project 2012

# MsTMIP "best estimate" vs GCP

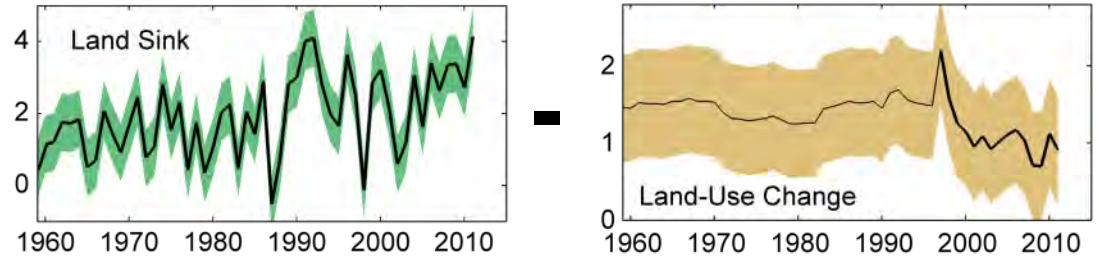
**SG3:**
- Climatology
- Land-use & land-cover change history
- Atmospheric $CO_2$

**BG1:**
- Climatology
- Land-use & land-cover change history
- Atmospheric $CO_2$
- N Deposition




"Residual land sink"



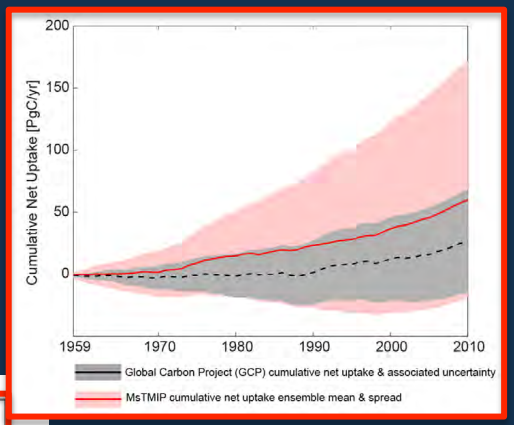

-

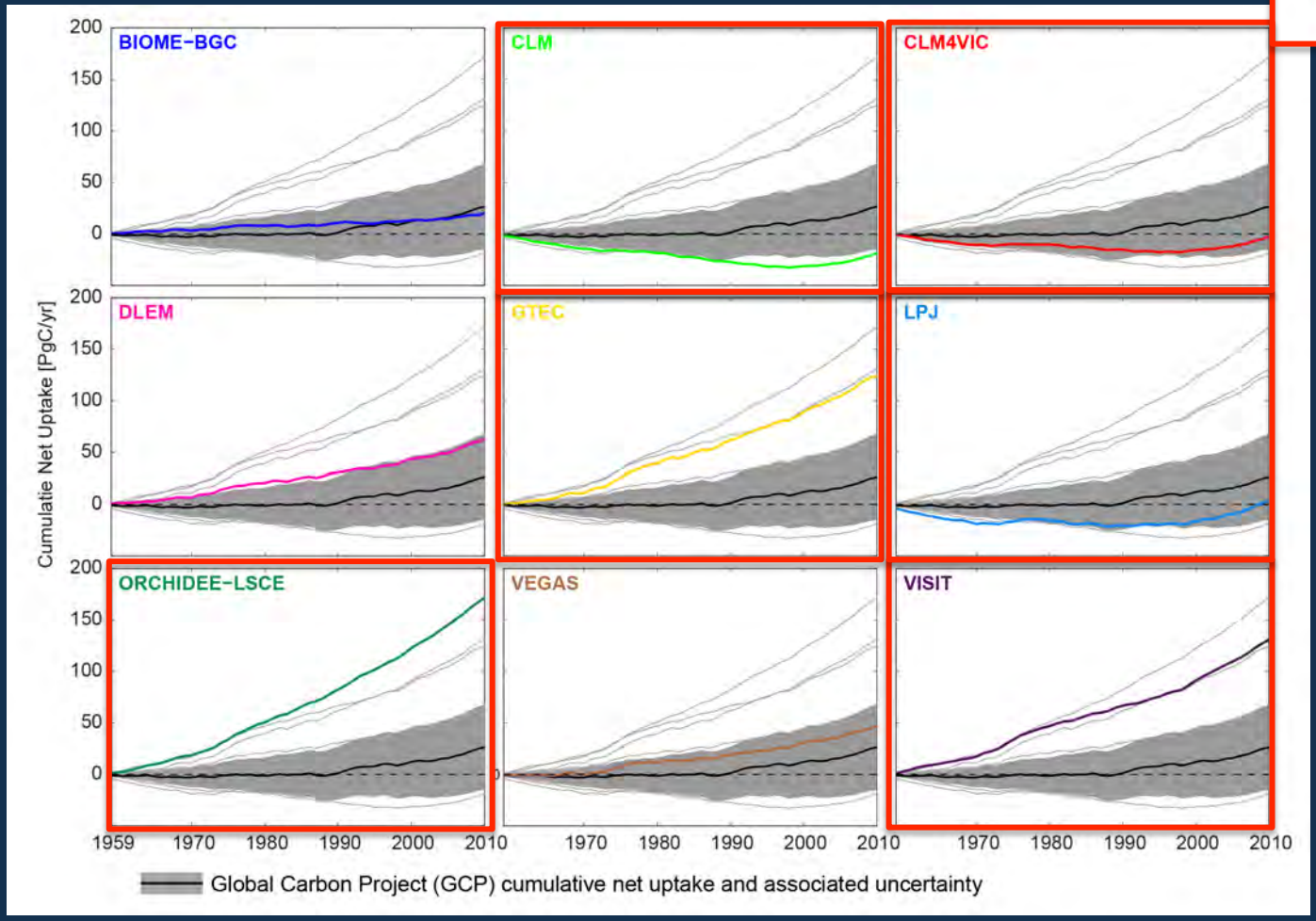



Sign convention:
(+) net uptake
(-) net release

Huntzinger et al., (in prep)

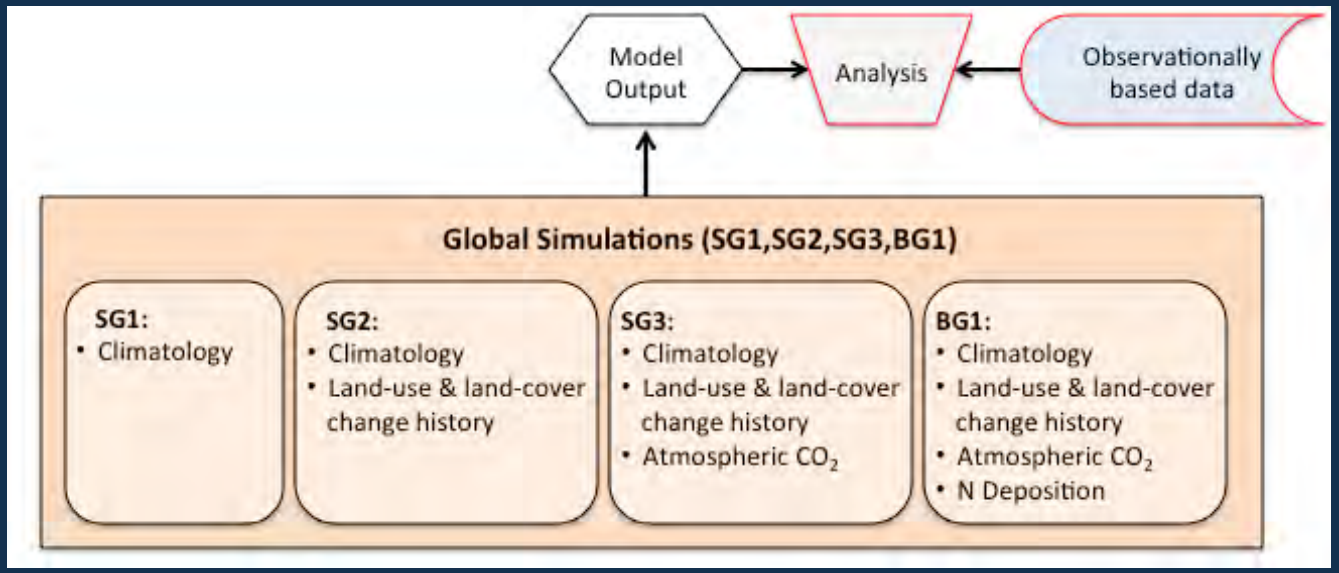
- Mean estimate from MsTMIP ensemble shows slightly stronger sink than GCP product.
- 3 models predict a net land sink much greater than the GCP product.
- For 3 models, over the last 50 years, the land surface has operated as net source of carbon.




Huntzinger et al., (in prep)

# How can we use site-level data to evaluate regional / global models?

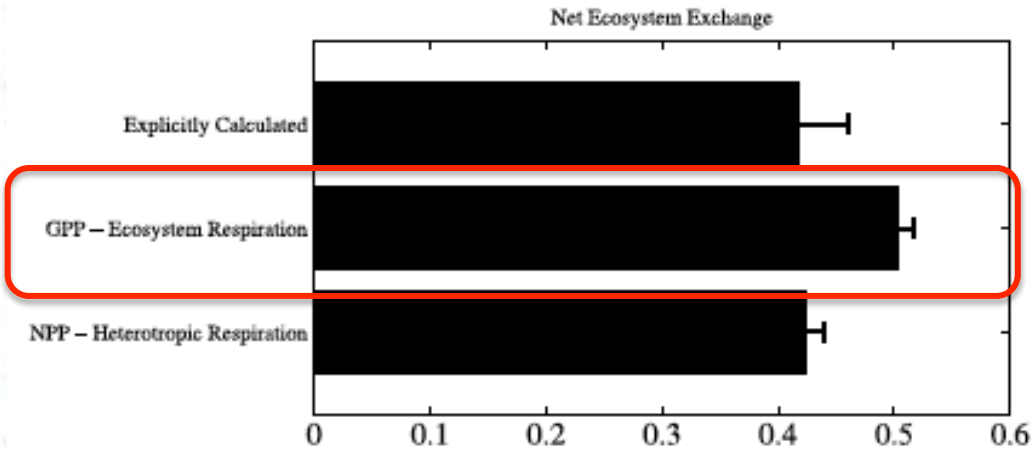


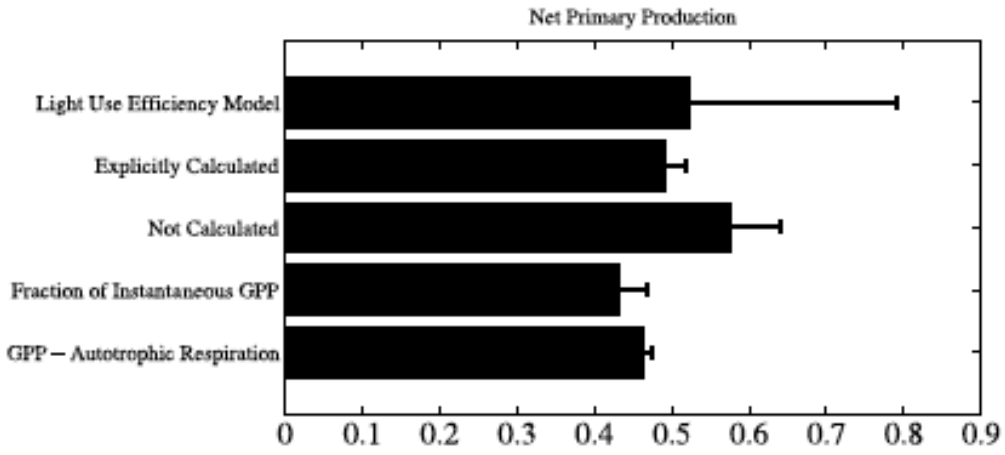

- Site specific simulations (e.g., Schwalm et al., 2010; Schaefer et al., 2012; Keenan et al., 2012)
- Compare regional/global runs to site data (Razcka et al., 2013)
- Gridded data-oriented products (Williams et al., 2009; Schwalm et al. in prep)
- …

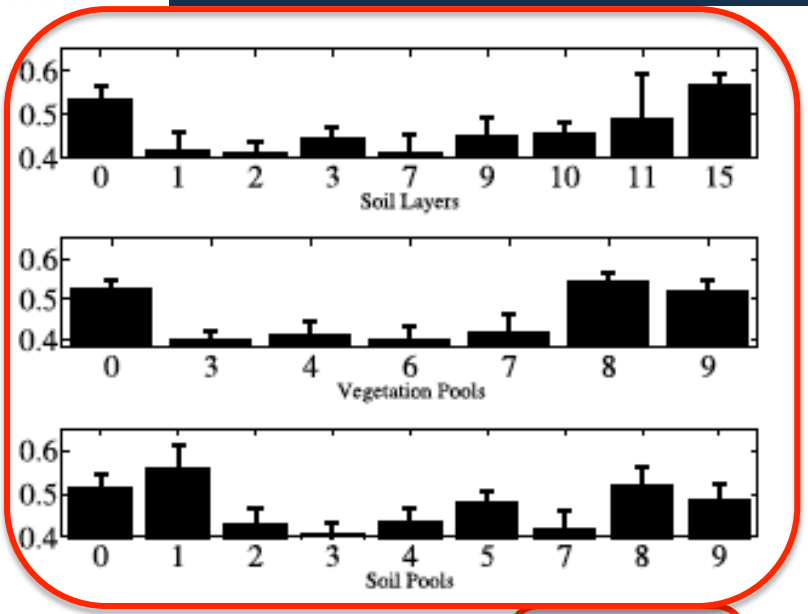
JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 115, G00H05, doi:10.1029/2009JG001229, 2010

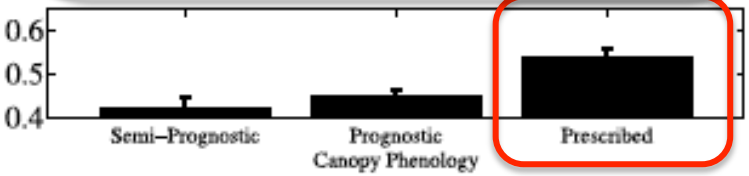
# A model-data intercomparison of $CO_2$ exchange across North America: Results from the North American Carbon Program site synthesis

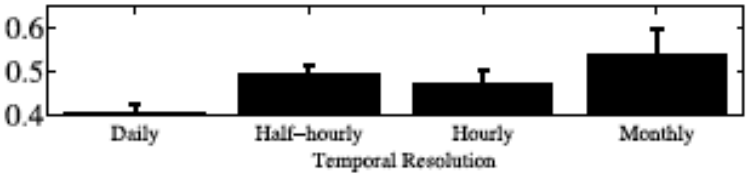
## Site specific simulations



JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 117, G03010, doi:10.1029/2012JG001960, 2012

specific
ulations

**A model-data comparison c**
**from the North American C**

Kevin Schaefer,[1] Christopher R. Schv
Jing M. Chen,[6] Kenneth J. Davis,[7] D
David Y. Hollinger,[10] Elyn
Andrew D. Richardson,[13] A
Hans Verbeeck,[18] Ryan And
Jiquan Chen,[23] Peter S. Cur
Christopher Gough,[27] Robe
Beverly Law,[31] Shuguang L
Roser Matamala,[34] J. Harry
Walter Oechel,[38,39] Changhu
Nigel Roulet,[42] Hanqin Tian
and Xiaolu Zhou[40]

Received 20 January 2012; revised 16

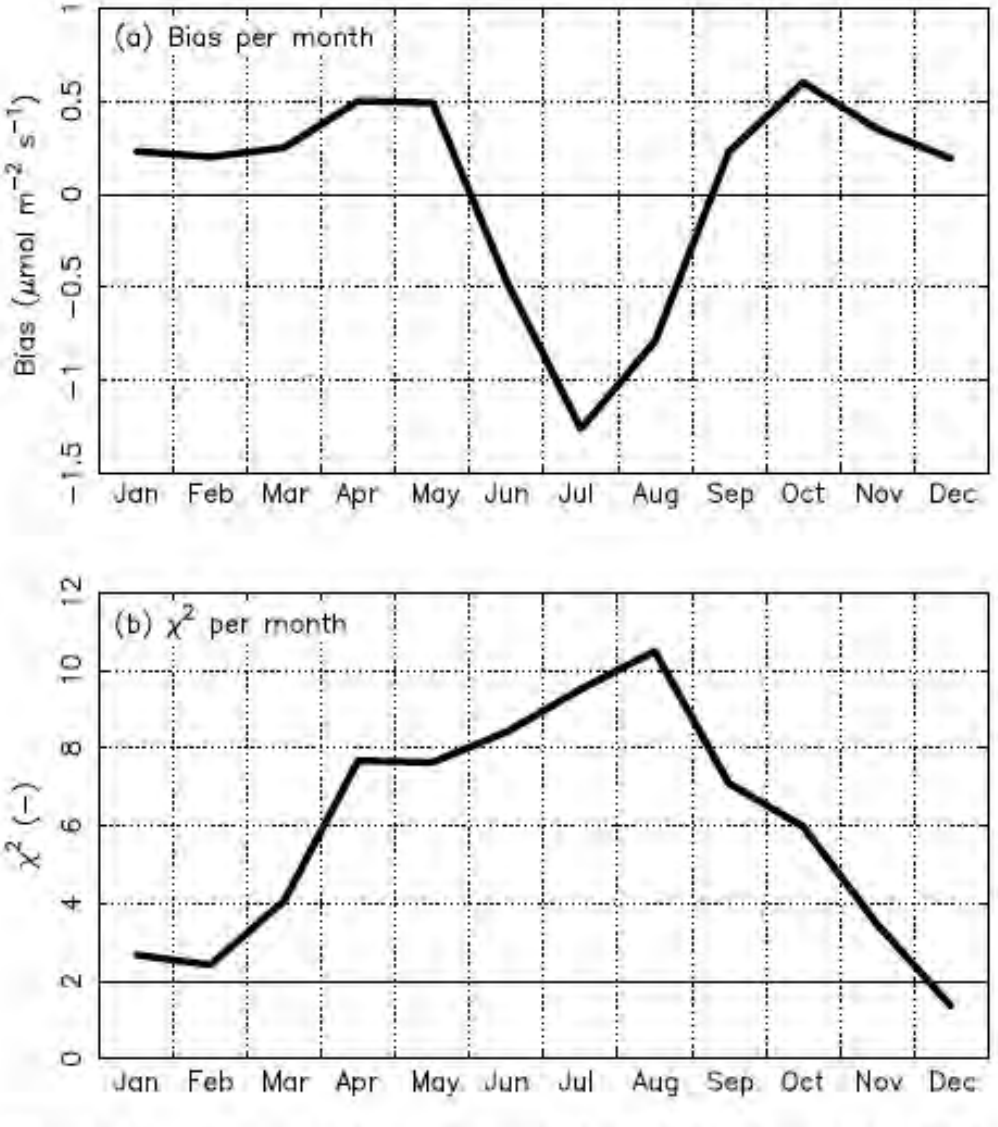
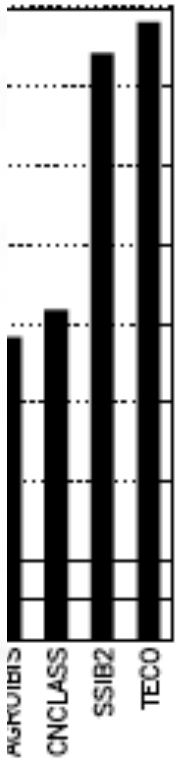



**Figure 2.** The monthly average bias in (a) simulated GPP and (b) monthly $X^2$ based on all 627 simulations from all models. An $X^2 < 2.0$ indicates marginal performance.



Global Change

# Terrest

## va

T. I
DI
DA
BR
HA


Fig. 2 The
mary proc
for indivic

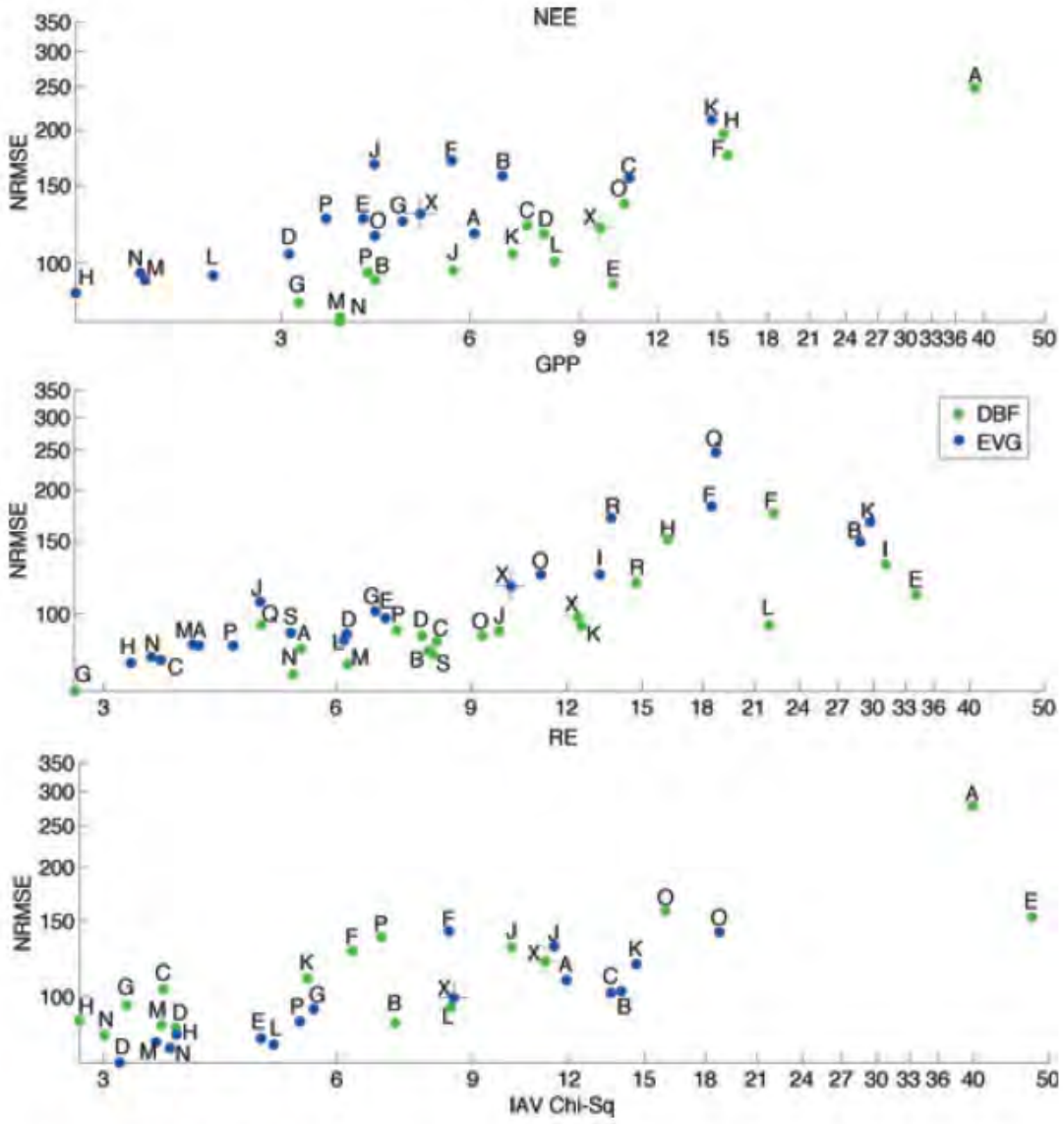


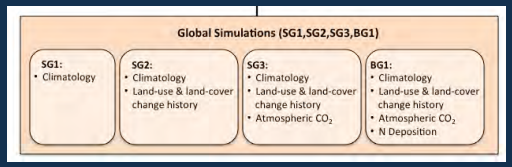

Fig. 3 Statistical comparison (on a log-log scale) of model performance (normalized root mean square error vs. $\chi^2$ statistic) for interannual variability (IAV) in annual totals of net ecosystem exchange (NEE), gross primary productivity (GPP) and ecosystem respiration (RE) for the two plant functional types (DBF (green): Deciduous broadleaved forests; EVG (blue): Evergreen needleleaf forests). See supplementary material for graphs with error bars (Fig. S1, S2).

Site sp
simula

# Using site level data to compare to site level runs

## Opportunities

- Can tell us something about potential model deficiencies
- Quantify uncertainties that arise from model structure, input data biases - depends on study design
- Guide model development/improvement




## Challenges

- Determining how site-level performance translates to performance of model at larger scales
  - If a model does well at the site level, does that mean we can trust its regional/global predictions more?
- Fluxes measured at site level do not account for impacts of fires, harvesting, land-use change, etc. operating over regional scales

# Using site level data to compare to site level runs

## Opportunities

- Can tell us something about potential model deficiencies
- Quantify uncertainties that arise from model structure, input data biases
- Guide model development/improvement

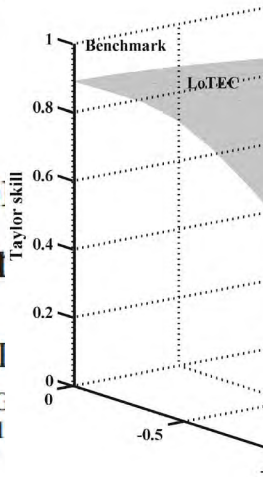
## Challenges

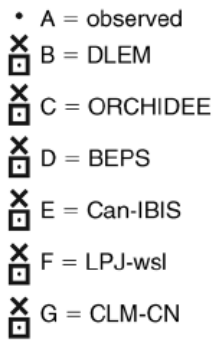
- Determining how site-level performance translates to performance of model at larger scales
  - If a model does well at the site level, does that mean we can trust its regional/global predictions more?
- Fluxes measured at site level do not account for impacts of fires, harvesting, land-use change, etc. operating over regional scales

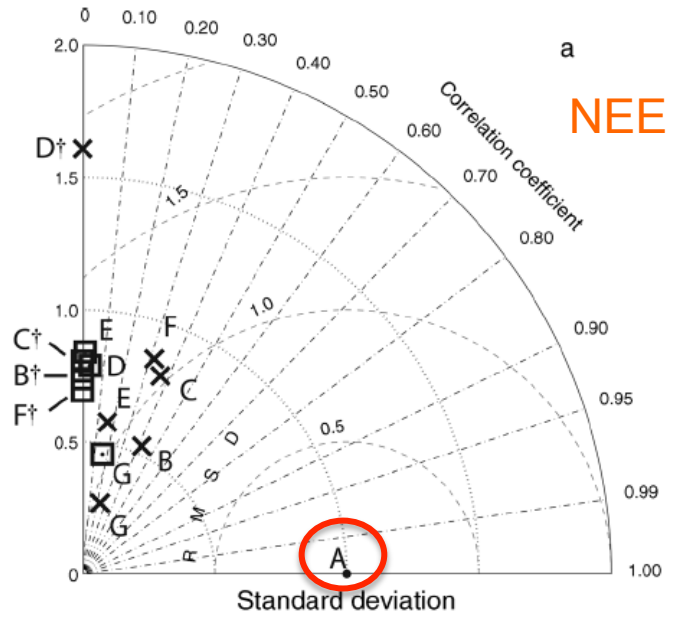
*Ecological Monographs*, 83(4), 2013, pp. 531–55
© 2013 by the Ecological Society of America

# Evaluation of co
# North Ar

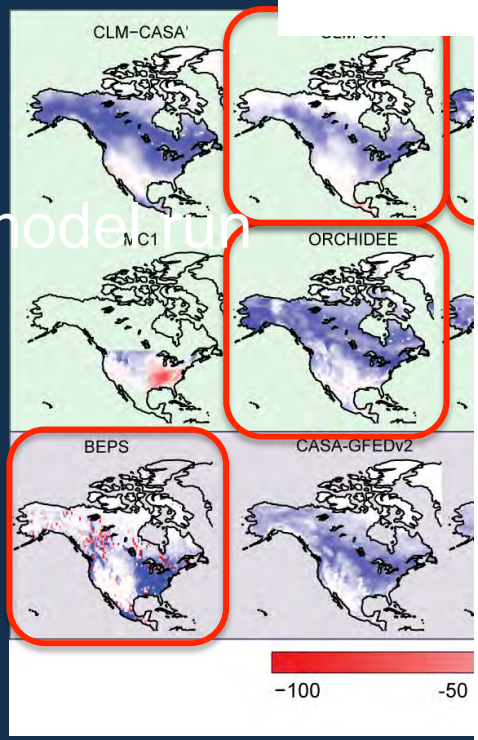
Brett M. Raczka,[1,15] Kenneth J. I
Andrew D. Richardson,[5] Jingfeng
Wilfred M. Post,[9] Daniel Ricciuto,[1]

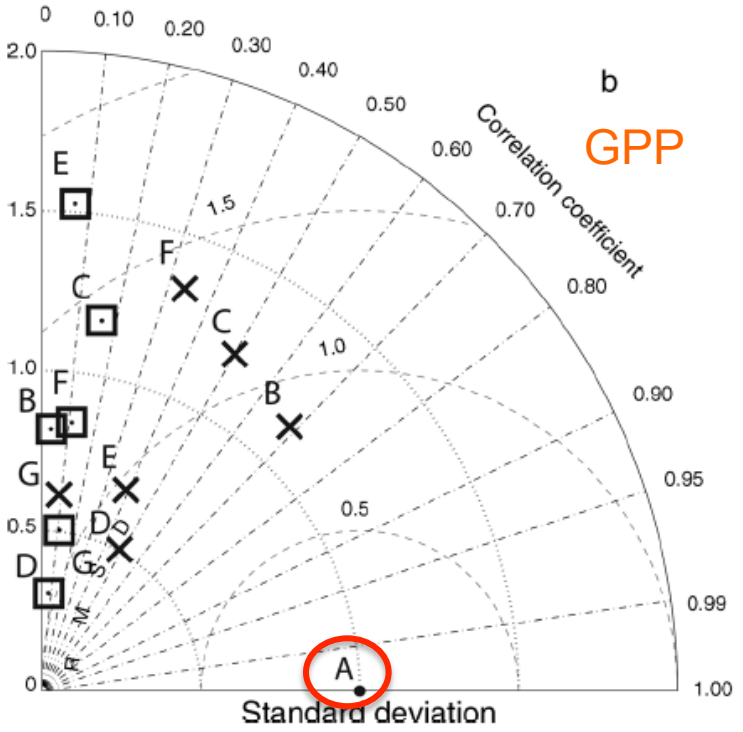



Boxes = regional-model run
X's = site-level run



# Using site level data to compare regional/global models

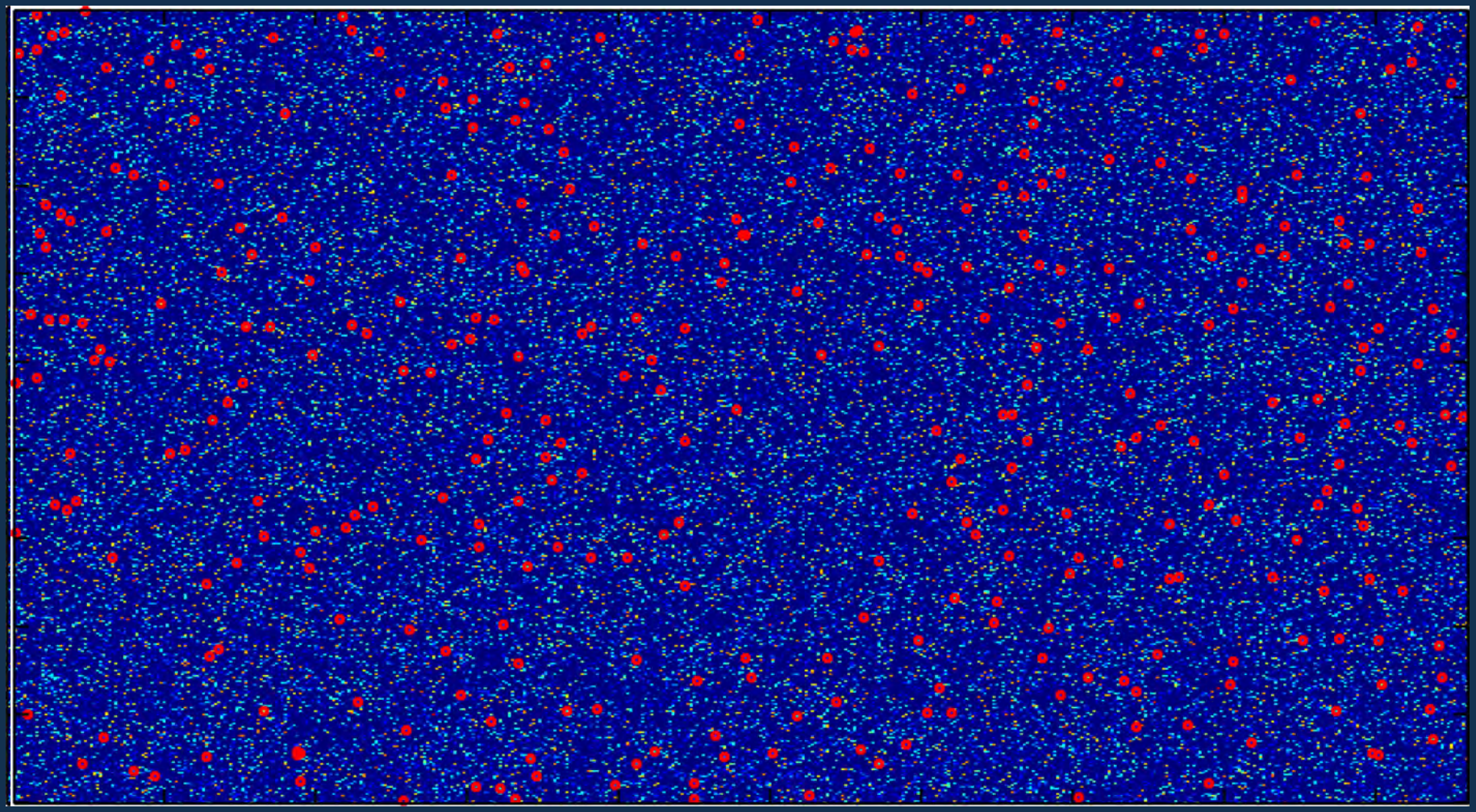
## Opportunities

- Compare model output to direct measurement of carbon and energy flux, etc.
- Compare functional responses / sensitivities in both observations and models
- Evaluate relative importance of environmental factors & climate extremes: observations compared with models
- Evaluate the impact of site versus regional/global climatology input data on model results

## Challenges…

# Challenge in using site level data to evaluate global models

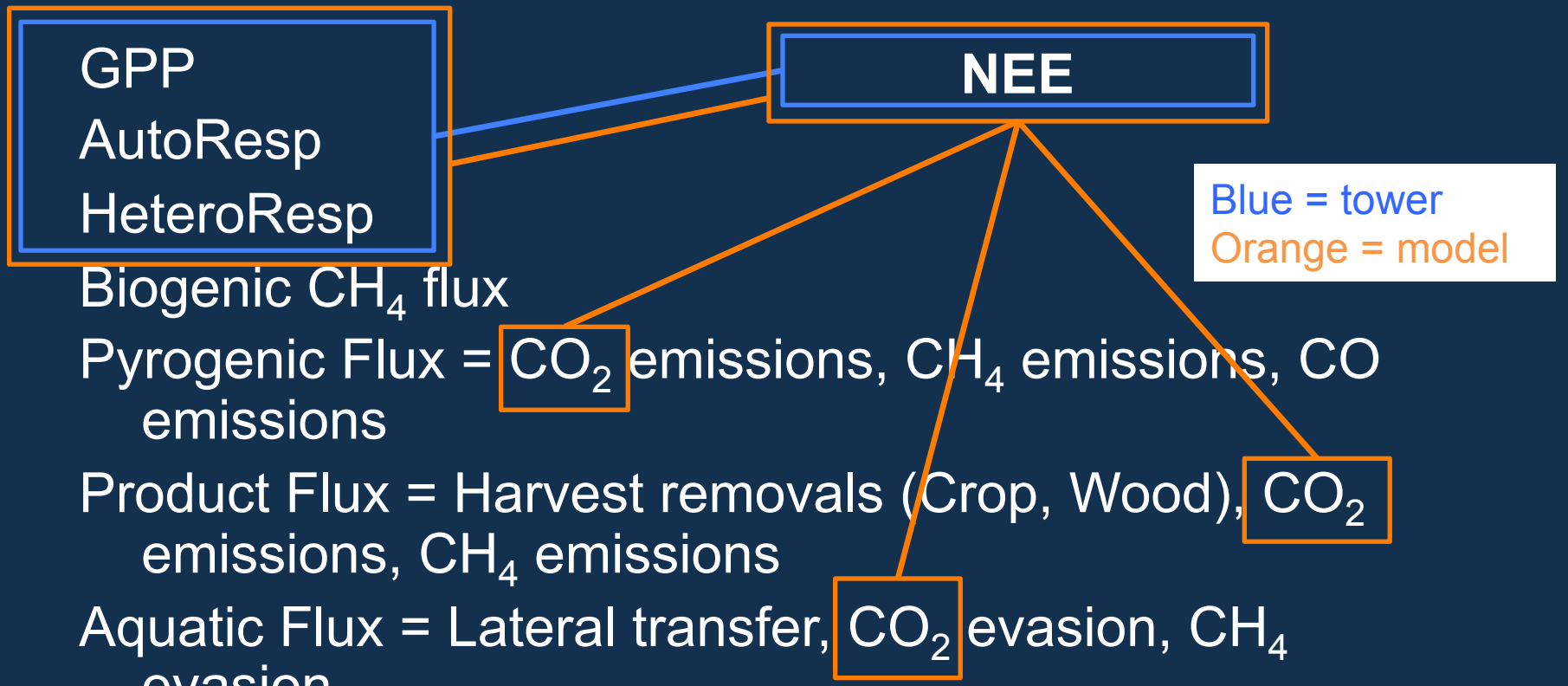
## Representation: scale mismatch & global coverage



From Christopher Schwalm

# Challenge in using site level data to evaluate global models

## NEE = NEE? Apples-to-apples comparison?



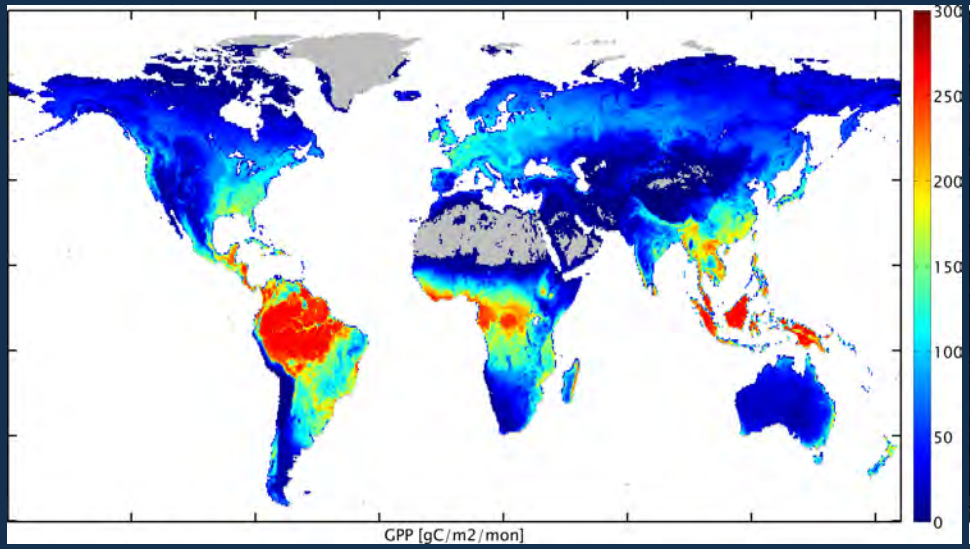

$$NEE = -NEP + Fire\_CO_2 + Product\_CO_2 + Aquatic\_CO_2$$

*From Dan Hayes (ORNL)*

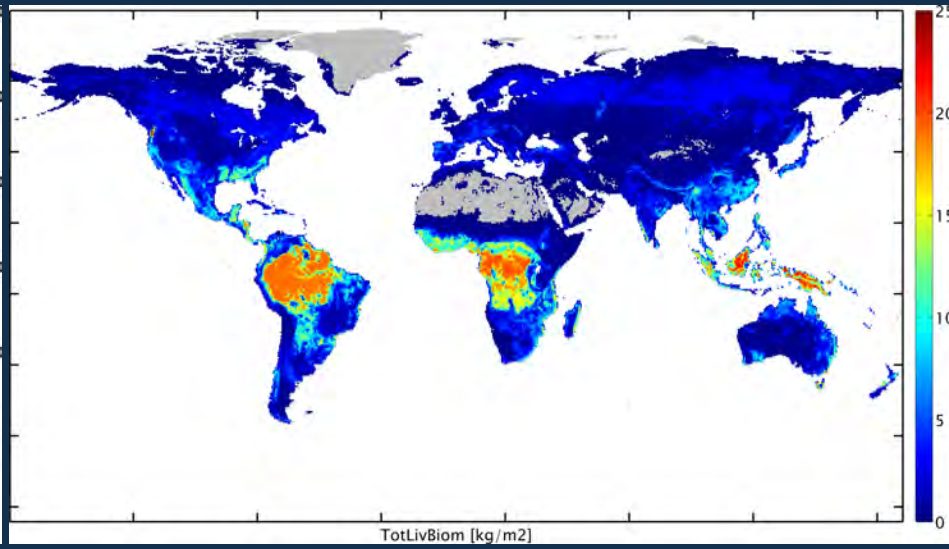
*Also see: Hayes, D. J., and D. P. Turner, EOS, 93(41), 2012.*

# Are there ways to overcome scaling issues?

- Up-scaled Fluxnet products or data oriented models (e.g., Jung et al., 2011; Papaled and Valenti, 2003; Yang et al. 2007)?
- Other gridded, observationally-based products (e.g., IPCC Tier-1 vegetation biomass from Ruesch & Gibbs, 2008)?




GPP from Jung et al. (2011)



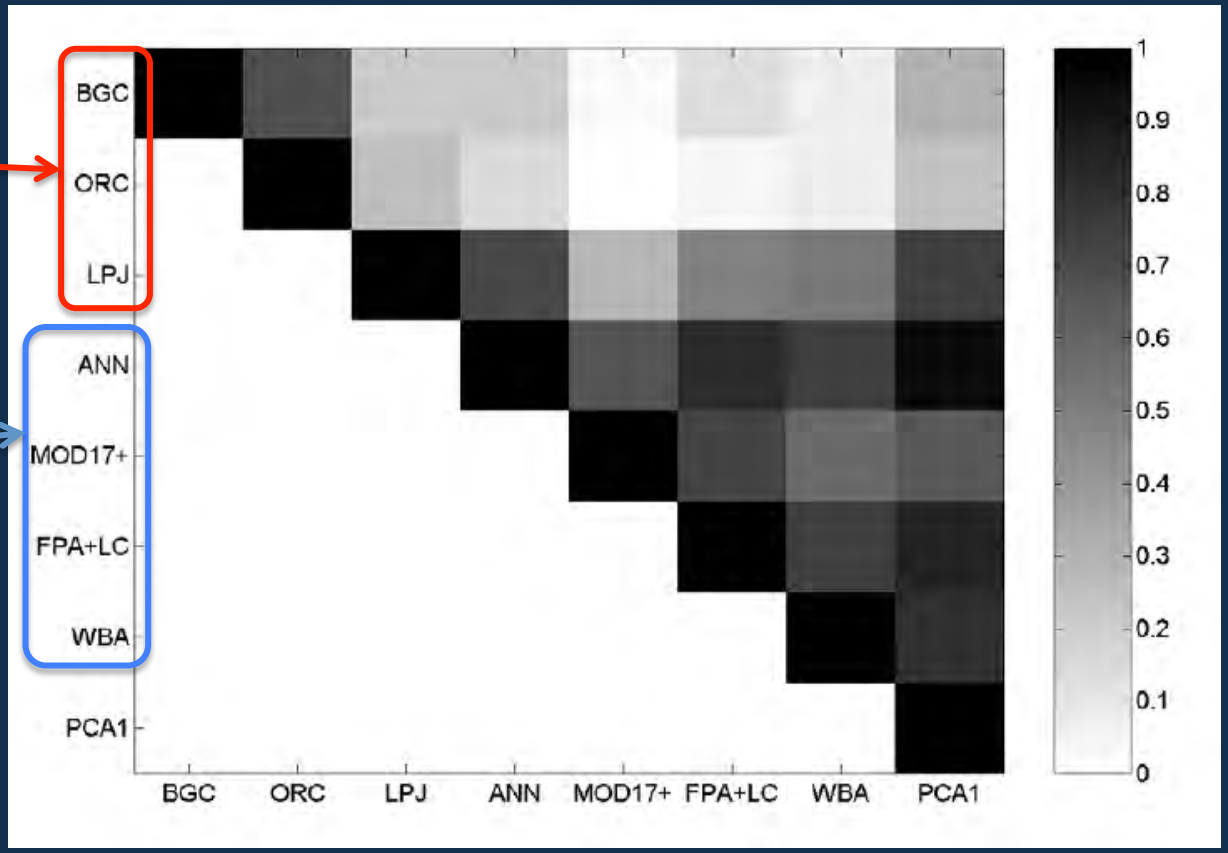

Total Living Biomass, Ruesch & Gibbs (2008)

# Difference (as $R^2$) in GPP from process-based models (TBMs) & data oriented models

Mean annual GPP for 36 major watersheds in Europe:

Process-based models

Model-data products



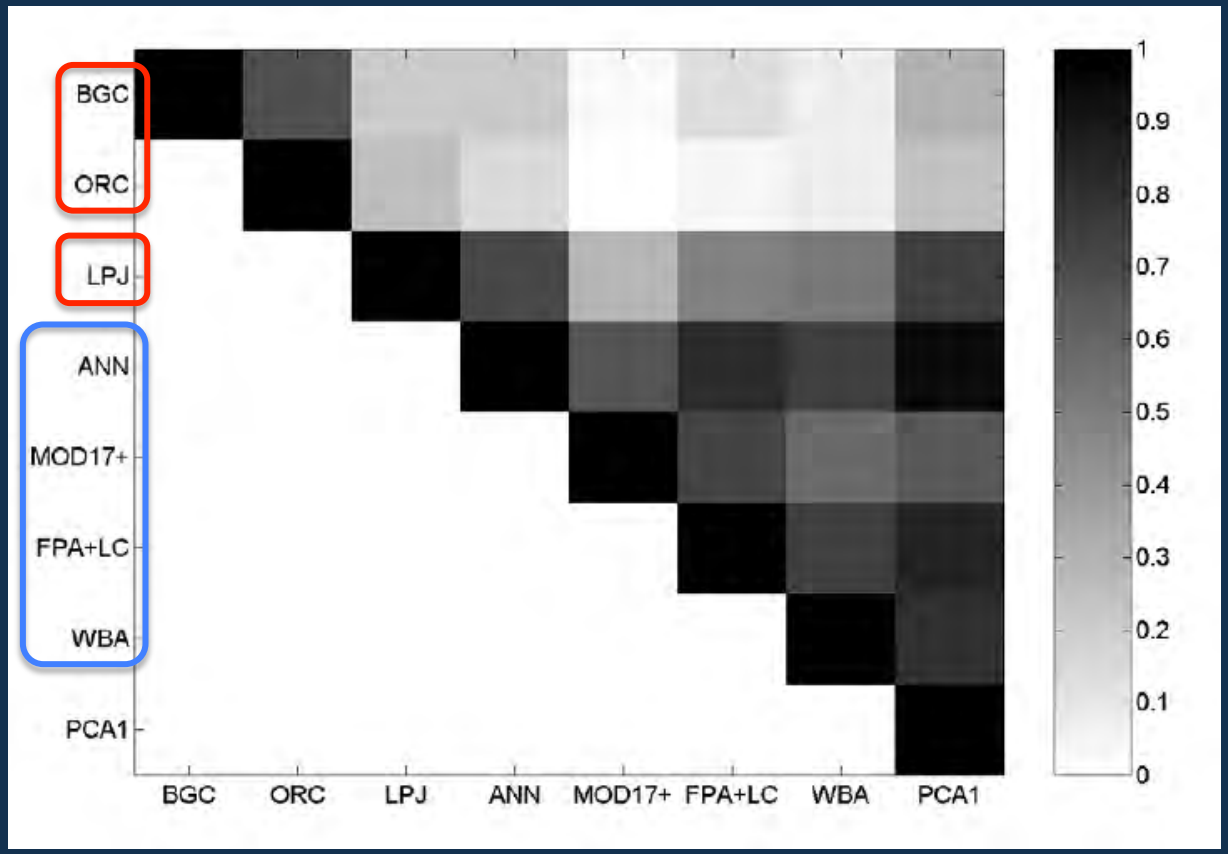

From Williams et al., Biogeosciences,2009

# Difference (as $R^2$) in GPP from process-based models (TBMs) & data oriented models

Evaluate deficiencies in model structure?

Assess confidence in model-data products?

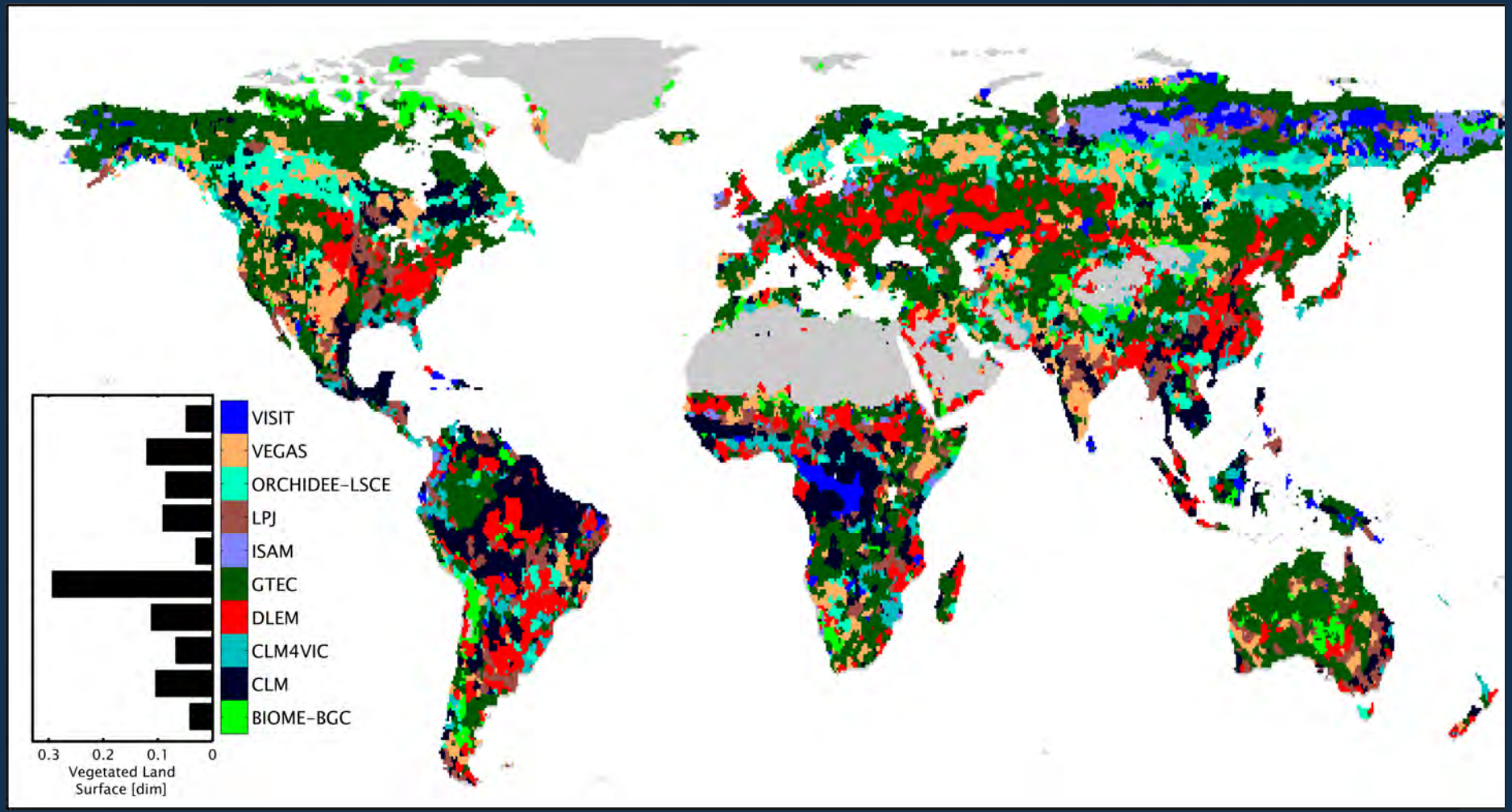
Mean annual GPP for 36 major watersheds in Europe:




From Williams et al., Biogeosciences,2009

# Combine reference data products with measures of model-”data” mismatch to determine model reliability

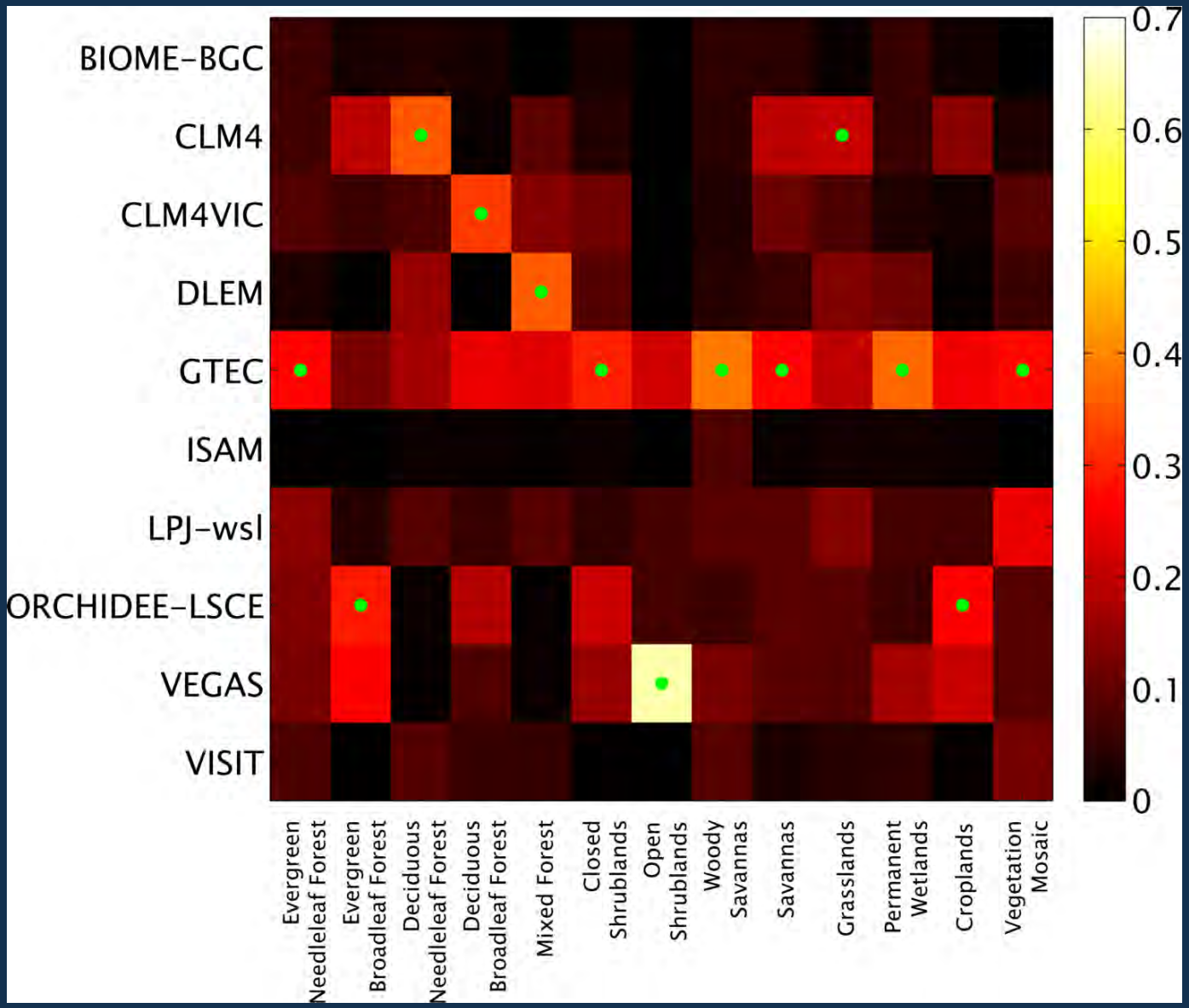
Spatial distribution of preferred model




Preliminary MsTMIP results

From Schwalm et al. (in prep)

# Preferred model by plant functional type




From Schwalm et al. (in prep)

# Regional and global comparison with “up-scaled” products

## Opportunities

- Can tell us something about potential model deficiencies
- Quantify uncertainties that arise from model structure, input data biases
- Guide model development/improvement

## Challenges

- Success of evaluations depends on quality of these model-data products
  - Uncertainty of products needs to be less than uncertainty in model estimates
- Depends on how well scale-mismatch is controlled for in the gridded products

# Closing thoughts

- Flux towers provide the only direct measurement of net ecosystem exchange
  - Essential tool for evaluating model estimates of land-atmosphere carbon exchange
- Challenges to using flux tower data to evaluate regional and global models
  - Representativeness
  - Differences in how fluxes are defined (or the scale at which processes influence measurements / modeled fluxes)
  - Uncertainty in models and in observations / data-oriented products
  - Could get the right answer, but for the wrong reason
- Perhaps greatest value of data from flux towers is to evaluate process representation
  - How do you scale this up to regional / global models?

# Acknowledgements


Funding:

- NASA Terrestrial Ecology Grant# NNX10AG01A
- Modeling and Synthesis Thematic Data Center at Oak Ridge National Laboratory (http://nacp.ornl.gov), with funding through NASA Terrestrial Ecology Grant # NNH10AN68I


MsTMIP Modeling Team Participants (team leads):

| Model Name | Affiliation (Team Contact) |
|---|---|
| Biome-BGC | NASA Ames (Weile Wang) |
| CABLE-JPL | NASA JPL (Joshua Fisher) |
| CABLE | University of Oklahoma (Francesc Montane) |
| CLASS-CTEM-N+ | McMaster University (Altaf Arain) |
| CLM | ORNL (Dan Hayes) |
| CLM4-VIC | PNNL (Maoyi Huang) |
| DLEM | Auburn University (Hanqin Tian) |
| ECOSYS | University of Alberta (Robert Grant) |
| GTEC | ORNL (Dan Riccuito) |
| HYLAND-JPL | NASA JPL (Joshua Fisher) |
| ISAM | University of Illinois Urbana Champaign (Atul Jain) |

| Model Name | Affiliation (Team Contact) |
|---|---|
| JULES-JPL | NASA JPL (Joshua Fisher) |
| LPJ-wsl | LSCE, France (Ben Poulter) |
| MC1 | Oregon State University (Dominique Bachelet) |
| ORCHIDEE-JPL | NASA JPL (Joshua Fisher) |
| ORCHIDEE-LSCE | LSCE, France (Shushi Peng & Gwenaëlle Berthier) |
| SiB3-JPL | NASA JPL (Joshua Fisher) |
| SiB-CASA | National Snow & Ice Data Center (Kevin Schaefer) |
| TEM6 | ORNL (Dan Hayes) |
| TRIPLEX-GHG | University of Quebec at Montreal (Chanqhui Peng) |
| VEGAS | University of Maryland (Ning Zeng) |
| VISIT | National Institute for Environ. Studies, Japan (Akihiko Ito) |